Michigan Animal Tissue Compost Operational Standard

October 11, 2007

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INTRODUCTION

Composting is a biological process that effectively changes animal tissues into a useful soil amendment or rooting medium. It is a controlled process requiring knowledge, skills, and consistent attention. It is not just above ground burial.

These operational standards have been written to allow people to comply with the composting portions of the Michigan Bodies of Dead Animals Act and accompanying Rules. It is written for those who have made a decision to compost to manage on-farm mortality, meat processing by-products, or carcasses found along roadways (whole bodies or as parts). These operational standards describe methods which may be used in Michigan, including: details about site selection, sizing the composting system, and how to manage the composting process most effectively. These standards do not include specific information about the microbiology of composting, the history of composting, the justifications for composting, composting equipment, and the composting of manures and other vegetative materials. Such information may be found in several of the supporting documents listed in the RESOURCES and REFERENCES section below.

TERMINOLOGY

Active composting - the accelerated decomposition of organic materials into carbon dioxide, water, heat, and compost. During active composting the temperature of compost increases to 100 to 150 degrees Fahrenheit and may remain in this range for several weeks, until decreasing to 100 degrees Fahrenheit or less. At this point the compost is not cured or stable, just deprived of oxygen and(or) moisture. With aeration and the maintenance of 40 to 60% moisture content in the compost, compost may be reactivated with temperature increasing again to greater than 130 degrees Fahrenheit. It will eventually decrease again to 100 degrees Fahrenheit or less. Michigan law states that compost batch temperature must be monitored at least once weekly. Properly timed aeration and moisture additions will allow active composting to continue in repeated cycles of active composting for months, with repeated temperature increases and decreases. Michigan law requires that each batch of animal tissue compost undergo a minimum of three heat cycles during active composting before final utilization as finished compost.

Aeration or aerate - the introduction of air into compost using any of the following methods: (1) Passive, using porous bulking agents or the movement of hot gases leaving a ventilated rotating in-vessel composting unit; (2) Active (mechanical), turning, or mixing using a loader or special windrow turners on an intermittent or regular frequency as determined by monitoring temperature; or (3) Forced, the forcing of air through compost on a continuous or scheduled bases using a designed system of perforated piping laid in the base layer of the compost or in the flooring or walls of the compost facility.

Afterbirth - fetal fluids, placenta, and fetal mortality.

Animal process operation - place where animals or animal tissues may accumulate in a non-production (no multiple-day care and feeding) setting such as a butcher shop, slaughtering facility, taxidermist, road commission, veterinary clinic, or market collection point. The Michigan Bodies of Dead Animal Act (Amended 2005) in Section 19, Sub-sections 3 and 4, is interpreted to mean that authorization (exchange of letters is suggested) by the Director of MDA is needed for composting by all animal process operations, since the animal tissue accumulated is not always clearly “normal natural daily mortality intrinsic to an animal operation under common ownership or management.”

Animal production operation - farm or farms where animals under common ownership or management receive care and feeding for the production of food, co-products, or pleasure.

Batch - compost accumulated in a planned period of time. Initial additions, or loading, of new dead animals and bulking agent (pile formation or placement into a contained, in-vessel system) is limited to a planned time period based on rate of mortality and an appropriately sized composting method. Batches provide for appropriately timed temperature monitoring, aerating, and utilization.

Bin - structure constructed to contain compost and able to withstand damage which may be caused by active composting and equipment used for compost aeration and movement. One wall should be reinforced to confine compost when mechanically moved.

Biofilter cap - layer of fresh bulking agent placed over a pile with the objectives of reducing odors and discouraging pests. Carbon-rich materials such as chopped bean stover, chopped corn stover, chopped straw, dried grass, grain hulls, chopped dried hay, and sawdust or shavings are preferred as biofilter materials. Nitrogen-rich materials such as animal manure solids, partially-decomposed feedstocks, green grass clippings, fresh hay, green leaves, and litter cake are less effective in controlling odors, insects, and vermin.

Bulking agent - material added to compost to provide nutrients, decrease bulk density, promote aeration, and remove heat. Synonyms commonly used for bulking agent include: amendment, medium, carbon source, and feedstock. The following may be used as compost materials alone or in a mixture: animal manure solids, chopped bean stover, chopped corn stover, chopped straw, cured or partially-cured compost, dried grass, grain hulls, grass clippings, hay, leaves, litter cake, sawdust which is unpainted and which does not have additives or preservatives, unpainted shredded bark that does not have additives or preservatives, unpainted wood chips that do not have additives or preservatives, and waste animal feeds. Bulking agent particle size or porosity, is important in maintaining aerobic conditions within the pile. If too fine, then oxygen will be lacking and if too coarse then the desired mix of nutrients (i.e. interface between tissue and bulking agent) will be lacking. A non-uniform, particle size range of 0.5 to 2 inches is recommended.

C:N – carbon to nitrogen ratio. Detailed description is provided below.

Compost – the rich earthy black material at the end of the composting process, derived from many different organic materials.

Curing - the period of time after active composting where decomposition occurs at a slow rate. Microbes slowly using the remaining available nutrients, with minimal respiration. Nearly all of the nutrients in the compost have become unavailable to the microbes or stable by the end of the curing stage..Cured compost contains slow-releasing plant nutrients and is not harmful to plants. Unlike actively decomposing feedstocks, cured compost does not tie-up large amounts of nitrogen and oxygen when mixed with soil. Curing compost does not reheat to temperatures of 130 degrees Fahrenheit or greater after aeration. Less heat production and lower temperatures are sustained during curing (range 60 to 100 degrees Fahrenheit). Cured compost may sometimes be described as “mature,” “stable,” or “done”. The desired maturity or stability of compost will depend on its intended use and may be determined by monitoring compost temperatures and (or) laboratory testing (Solvita™; oxygen consumption, carbon dioxide production). Curing time ranges from several weeks to one year or more. Curing of animal tissue compost, in part or whole, is not required by Michigan law.

Cycle - the increase and decrease in compost material activity. With proper conditions microbial activity increases and is reflected in greater temperature readings, however as resources (generally oxygen and water will become limited before carbon or nitrogen) become limited, activity diminishes, and so does temperature. With aeration and water addition compost batches will go through repeated cycles of active composting, with repeated temperature increases and decreases. Michigan law requires that each batch of animal tissue compost undergo a minimum of three cycles of active composting before final utilization.

Effluent - see Leachate**.**

Fleece blanket – fabric to completely cover compost material. Typically synthetic and breathable, fleece blankets conserve moisture during dry weather and shed precipitation during wet weather.

Finished - compost ready for final utilization as a soil amendment, plant fertilizer, or rooting medium. This may be through sale or application to crop fields owned by the composting owner/operator. Finished compost may not have begun curing or may have begun curing but not have continued to a point of stability or maturity where decomposition ceased entirely. Finished compost should be dark, humus-like with little odor, and free of any animal soft tissue. It does not need to be cured to be a soil amendment or fertilizer. However, curing is necessary for compost to be used as a saleable compost or rooting medium as curing results in the complete destruction of phytotoxins.

Fresh bulking agent - bulking agents of plant origin that have not been mixed with any animal tissue, product, or excrement and have limited odor-producing potential.

Forced aeration - air is pushed or pulled through compost feedstocks to speed the composting process. A blower and portable perforated piping may be laid in the base layer of the pile, or permanent perforated piping placed in the flooring or walls of the compost facility are used.

Grinding - the mechanical reduction of intact or whole animals or parts into smaller pieces.

In-vessel - composting within a container, may use passive, forced (and)or active aeration, to aggressively manage active composting (e.g. rotating drum, agitated bed, silo, rotating tube, rotating box, forced air box).

Leachate - any liquid leaving compost materials by running off the surface of the pile or flowing downward through the pores of the pile.

Normal or natural - carcasses or tissue by-products accumulated as a result of the ordinary predictable day-to-day operations of caring for, keeping, and harvesting animals.

Passive aeration - air exchange within the composting feedstocks accompanies heat release with fresh air pulled into the lower portion of the pile as heat pulls gases out of the upper portion of piles. Compost feedstocks must be actively aerated by turning or mixing to increase porosity (aerate) at least two times to encourage decomposition. Forced aeration is not used.

Pile - the heap or mound of compost materials. An open pile has no structure to contain the compost or shape the pile. Alternatively, a pile may also be within a bin structure, or shaped into an open-windrow.

Phytotoxin – poisonous (to other plants, animals and humans) substance produced by plants

Site - the location on premise where composting occurs.

Static - a pile that is left to stand motionless or idle. A static composting pile may be aerated passively, by periodic agitation, mixing or turning, or by force.

Windrow - long, relatively narrow, low pile.

SELECTING A COMPOSTING METHOD

There are four general composting systems or methods which may be used to compost animal tissues. Each requires orderly formation, identification, and management of composting batches. Passive, forced, and(or) active aeration may be used with each.

(1) Open pile
(2) Bin
(3) Windrow
(4) In-vessel

These four methods vary in their speed of composting, environmental risk, expense, and aesthetics. Generally, the following is true with any of the four methods:

- Total composting time and space are reduced with forced (continuous or scheduled intermittent) or temperature-based active aeration.
- Compost material may become dry and water must be added. Forced and active aeration increases the rate of drying (when adding water, use caution to avoid leachate).
- Forced and active aeration increase cost.
- Faster composting with temperature-based active aeration
- Active aeration (turning and mixing) is not necessary with forced aeration
- Forced aeration is more expensive and lessens size of composting site because space is not needed by equipment
- Installation and removal of pipes if laid in feedstocks require greater management
- Pipes become plugged and equipment failure with forced aeration
- Grinding decreases composting time by reducing tissue size.

- Grinding also reduces the amount of bulking agent, as the entire carcass need not be surrounded by 0.5 to 1 foot of bulking agent.

The advantages and disadvantages of each method are listed below:

Open pile

Advantages
- Require less labor and management as minimal active aeration is required
- Easy to designate batches
- Low capital costs
- Makes use of existing farm machinery
- Larger batches for large carcasses
- Site may be more remote

Disadvantages
- Composting process is slow with minimal active aeration requiring more space
- With large piles, compost materials may become compacted, anaerobic, and odorous
- Heat is not uniform throughout pile, micro zones of less pathogen and seed kill may exist
- Heavy precipitation may cause runoff, leaching, and anaerobic/odorous conditions, but may be alleviated with use of fleece blanket over the pile
- Winds may move amendments and uncover animal tissue but may be alleviated with use of fleece blanket over the pile
- Driving of large equipment is more difficult year-round with freezing, thawing, and precipitation

Bin

Advantages
- Easy to manage batches and greater control of composting process
- If roofed, little or no risk of precipitate leachate
- Existing facilities or materials may be used
- Easy to designate batches
- Makes use of existing farm machinery
- Greater control of scavenging animals

Disadvantages
- Greater cost associated with construction of facility, especially with use for large carcasses
- If roofed, compost feedstocks may dry more quickly, requiring moisture additions. Alternatively, a roll-back tarp roofing may be used

Windrow

Advantages
- Composting activity is accelerated with active aeration
- Easier to actively aerate using designed turning equipment
    - With frequent turning mixing and heating is more uniform
- Turning is not required if forced aeration is employed

Disadvantages
- Similar to piling (as written above)
- Greater surface area per mass of tissue than piles in order to facilitate aeration if done mechanically with large equipment
- Aeration through turning requires a schedule and more labor
- Greater equipment cost if turning is done using specialized equipment
- If a loader is used to aerate (turn), then more space is required
- Manager may forget to delineate a batch and be tempted to keep making windrow longer

In-vessel

Advantages
- Least vulnerability to weather
- Least odor problems
- Greatest control of composting process

- Site space efficient
- Less labor because of automated active aeration
- Uniform heating throughout compost material
- Contained systems give greatest fly, vermin, and scavenging pest control

Disadvantages

- Greater capital costs
- Mechanical breakdowns
- Dry quickly and moisture additions must be made without leakage
- Operation on a continuous flow basis does not result in a cured, stable compost upon removal from the container.

MICHIGAN COMPOSTING SYSTEM REQUIREMENTS

There are two basic categories of animal production operations or farms outlined in the BODA rules: Those producing over 20,000 lbs. of total dead animal tissue annually, and those producing 20,000 lbs. or less..

Animal production operations producing over 20,000 lbs. annually and all animal processing operations are required to compost in or on a liner meeting the NRCS 313 standard for liners (see SELECTING A COMPOSTING SITE section). Although there are some variations, this can typically be accomplished on a concrete "pad" meeting certain criteria. At this type of site, all leachate and runoff from the "pad" must be collected, stored, and disposed of in a manner consistent with the environmental considerations discussed below (see SELECTING A COMPOSTING SITE section). This "pad" method is the preferred method for all farms because following the appropriate standards ensures adequate environmental protection. This method also provides many management advantages, which may provide long term economic benefit.

Animal production operations producing 20,000 lbs. and under annually may choose to compost on the soil surface of land used for crop production, provided the methods referenced in the sections below are followed (see SELECTING A COMPOSTING SITE and MANAGING THE COMPOST PROCESS EFFECTIVELY sections). With the "no pad" method, collection of leachate is not required. However, the final disposition of leachate generated must not cause a violation of any other federal, state, or local laws. Farms electing to compost on the soil surface shall not exceed 20,000 lbs. of dead animal tissue produced in any twelve month period.

Category Determination. Animal production operations or farms and animal processing operations are required to maintain the following records for all dead animal tissue produced: species, age class, and estimated weight (Table 1).

Table 1. On-farm mortality rates and average weights

Species	Mortality rate, %	Average weight, lb.
Swine[1]		
Stillbirths	0.5-1	2-3
Farrow to wean	10-15	10
Nursery	2-5	30
Grow/Finish	2-8	160
Breeding herd	2-6	350
Poultry[2]		
Laying hen	14	4.0
Broiler breeding hen	11	7.0
Broiler breeder pullet	5	4.3
Commercial egg pullet	5	2.8
Broiler	5	4.5
Roaster	8	8.0
Turkey hen	6	16.0
Turkey tom	9	25.0

Beef[3]		
Still-births	2	90
Pre-wean	1	600
Feedlot	1-2	850
Cows	2-3	1250
Dairy[4]		
Pre-wean	8-9	90
Heifers	2	600
Cows	4-5	1400
Sheep and goats[5]		
Pre-wean	10-12	8
Feedlot	2-4	50
Adults	4-6	80-170
Horse[6]		
Foals	3-4	100
Adult	1-2	1200-1500

[1]D.W. Rozeboom, Department of Animal Science, Michigan State University
[2]Barker, 1996
[3]USDA:APHIS, May 1998 and May 2000
[4]USDA:APHIS July 2002 and June 2003
[5]USDA:APHIS December 2003 and 2001
[6]USDA:APHIS August 1998

Presented below are two ways to estimate annual mortality production. If your total annual mortality estimate is approaching 20,000 lbs., you may want to consider using the pad option to account for additional inputs to the composting system such as afterbirth and yearly variability in mortality rates:

1. Many animal production operations or farms will know mortality numbers or rates associated with their particular operation. If mortality numbers are known, total annual mortality production can be calculated in the following manner:

   For each species and age class within the species, multiply the total number of mortalities (from on-farm records) over the course of a year by the average weight of that age class in pounds. The results of each age class should then be added to calculate total mortality production in pounds (see Table 2 for example calculation.

Table 2. Example calculation of weight of annual mortality if farm specific mortality rate is knows.

	Number of mortalities		Average weight, lb.		Total weight, lb.
Calves	12	x	150	=	1,800
Heifers	6	x	750	=	4,500
Milking and dry cows	15	x	1,300	=	19,500
Total weight of mortality per year					28,500*
*Composting must be performed on a pad meeting NRCS criteria.					

2. If the farm specific mortality rates are unknown, total annual mortality production can be estimated from the industry averages presented in Table 1.

   For each species and age class, multiply the average annual mortality rates from Table 1 by 100 by the average on-hand inventory of each species and age class by the average weight of each species and age class. (see Table 3 for example calculation).

Table 3. Example calculation of weight of annual mortality if the farm specific mortality rate is unknown.

	Mortality Rate		Average Stock on Hand		Average weight (lbs)		Total
Calves	0.09	x	70	x	90	=	567
Heifers	0.02	x	120	x	600	=	1,440
Milking and dry cows	0.05	x	175	x	1,400	=	12,250
Total weight of mortality per year							14,257**
**Composting may be done on soil as long as the 20,000 lb. criteria is not exceeded.							

A Microsoft® Office Excel Spreadsheet called *Spartan Compost Sizer* is available from Michigan State University (at http://www.canr.msu.edu/dept/ans/community/people/rozeboom_dale.html or Swine Nutrition & Production Management, 2209I Anthony, Department of Animal Science, Michigan State University, East Lansing, MI 48824-1225) to estimate mortality accumulation in a given time period

SELECTING A COMPOSTING SITE

The composting site must be selected and/or graded to direct surface runoff away from the site and prevent leachate from contacting surface or ground waters. The site must be accessible year-round, in all sorts of weather. The composting pad surface must be able to withstand the movement and weight of a loader in wet conditions (spring, fall, and rain in winter with freezing and thawing). Consultation may be sought with Michigan State University Extension or Michigan NRCS for assistance in determining site size and a batching schedule. The *Spartan Compost Sizer* is also a tool to be used to estimate the size of the composting facility or structure needed with a given compost method (available from Michigan State University at http://www.canr.msu.edu/dept/ans/community/people/rozeboom_dale.html or Swine Nutrition & Production Management, 2209I Anthony, Department of Animal Science, Michigan State University, East Lansing, MI 48824-1225). *Spartan Compost Sizer* may be used to determine the size of bins, the size of the pad upon which open piles or windrows are laid when composting, and the number of bins, piles, or windrows needed to deal with the amount of animal tissue generated by a farm.

The location shall minimize the impact of the facility on odor and other air quality issues affecting neighboring residences, as well as minimizing the impact of the facility on surface and ground water resources. Consider prevailing winds**,** property lines, recreational sites, aesthetics, and landscaping.

To minimize the potential for contamination of surface waters, composting sites should be located outside of floodplains. However, if site restrictions require location within a floodplain, the site should be protected from inundation or damage from a 25-year flood event. An un-permitted discharge to surface waters from the composting site due to precipitation events (either by overland, drainage tiles, or other mechanisms) is in violation of Michigan Law.

The location of the animal mortality composting facility should be consistent with the overall site plan for the livestock or poultry operation. Consider on-farm traffic patterns, and provide adequate space around the composting facility for loading, unloading, and mixing equipment access.

All composting sites must meet the following criteria:

- Well drained with a minimum setback of 200 ft from waters of the state (this includes: lakes, streams, wetlands, sinkholes, seasonal seeps, or other landscape features that indicate the area is hydrologically sensitive).
- A minimum of 2 ft above the seasonal high water table as defined by NRCS 313 Waste Storage Facility dated 11/05
- A minimum of 200 ft from any well
- A minimum of 200 ft from the nearest non-farm residence

Animal production operations accumulating **MORE** than 20,000 pounds of mortality annually and all animal processing operations shall follow the following criteria:

- Composting shall be done on an improved surface as defined by NRCS 313 Waste Storage Facility Conservation Practice Standard, dated 11/05 (see section on Liners), and designed to withstand anticipated loads from the equipment used for placement, aeration and movement of compost materials.
- Existing concrete surfaces or structure may be used if it meets the following criteria:
  - An evaluation of the concrete surface or structure:
    - This can be accomplished by a visual inspection of the exterior and/or interior for structural soundness and/or review of the construction/as-built design documentation where available.
    - Walls appear to be vertical with no significant wall movement (bowing), where applicable
    - No significant cracking
      - Significant cracking is defined as any crack 0.20 inches wide or greater; the concrete surface of a displacement out of plane of > 1/8 of an inch. Hairline cracks are not considered significant
    - Inactive cracks are properly sealed
    - Document that there is an appropriate floor for the anticipated loads (where applicable).
    - Determine that any leakage from walls and the wall to floor joint is collected and controlled properly
- All leachate and runoff generated at the site during active composting and curing, shall be managed with at least one of the following:
  - Reintroduced into the compost pile
  - Diverted to a treatment system meeting the criteria in NRCS 635 Wastewater Treatment Strip Conservation Practice Standard 9/06
  - Overall management of leachate that is NOT collected and diverted to long term storage, management provision must be made to dispose of the leachate within a timely manner. Management provision of leachate is critical during warmer weather as excessive odors could be generated.
  - Collected and stored in a storage facility with a liner meeting the criteria defined in NRCS 313 Waste Storage Facility Conservation Practice Standard, 11/05

Animal production operations or farms accumulating **LESS** than 20,000 pounds of mortality annually shall meet the following criteria;

- A new composting site shall be selected for use annually and not revisited for 10 years
- The site must be on land used in agricultural crop production.
- Windrows should be made parallel to the slope so runoff can flow away from the site and prevent ponding on the uphill side of the windrow/piles.
- In order to prevent leachate or nutrient rich runoff from impacting water resources mortality composting sites shall:
  - Maintain all runoff controls to keep the site high and dry.
    - A cover fabric for composting may be used in order to shed excess rainfall and reduce the generation of leachate from the pile.
  - The site must not be directly above any subsurface field drains**,** as movement of nutrient rich runoff to surface waters from artificially drained crop land is a documented resource concern.
    - Consideration must be made when choosing a composting site in areas where subsurface field drains exist as research as shown that subsurface field drains can pose a risk to surface waters at the drain outlets.
      - Refer to the Agricultural Engineering Information Series publication 669, “Capturing Land-Applied Manure in the Root Zone, Part 2: Tile-Drained Land” http://www.maeap.org website under Livestock, Publications; “Capturing Land Applied Manure: Tile Drains” for additional information on managing and actions to consider when working on subsurface drain land.
    - An unpermited discharge to surface waters from the composting site due to precipitation events (either by overland, drainage tiles, or other mechanisms) is in violation of Michigan Law.
  - Site runoff must be managed to prevent ponding in a low area from occurring. The runoff could be directed to a well vegetated area without causing erosion.
  - Runoff or seepage from surrounding landscape that drains onto the site must be diverted away.

THE COMPOSTING PROCESS

Composting starts when the animal tissue is laid in a bulking agent such as sawdust. Almost immediately microorganisms start consuming nutrients and respiring. Temperature in active compost feedstocks rises to 100 to 150 degrees Fahrenheit and may repeatedly do so over the course of several weeks or months with aeration. Compost is considered finished based on its planned use as a soil amendment or rooting medium, and its aesthetic acceptability. In the context of animal tissue composting, finished and cured are different terms, with Michigan law requiring that compost be finished. Complete curing is not required. A period of curing may follow active composting, but is not necessary. Curing is composting, but at a slower rate and with lower temperatures. The curing portion of the composting process would continue until all nutrients are consumed by microorganisms; however it is botanically useful long before that point.

Composting activity diminishes over time as available nutrients for microbial growth diminishes, provided moisture and oxygen are not limiting. Consequently and historically, the descriptive terms “active” and “curing” have been used to qualify the composting process over time. These terms are accurately used in describing the composting of animal tissue in all systems. When composting in static piles or batches the terms “primary” and “secondary” have been used to describe management phases of composting distinguished by a turning, moving, or mixing event, but they do not accurately describe the progress of the composting process.

Active composting occurs under the following conditions:

- Carbon-to-nitrogen ratio (C:N; on weight basis) between 15:1to 40:1.
- Moisture content, range of 40 to 60 %.
- Oxygen concentration of greater than 5%
  - Density (lbs./yd3), range of 500 to 1200.
- pH, range of 5.5 to 9.0.
- Temperature (degrees Fahrenheit), range of 100 to 150.

These conditions are critical for microbes to flourish, to minimize odors, and to produce quality finished compost. They are achieved by having the proper mixture of bulking agent, animal tissue, water and air in proper proportions. This sometimes is called the compost recipe. *Spartan Compost Optimizer* is a Microsoft® Office Excel Spreadsheet available from Michigan State University to plan or assess the C:N, moisture content, and bulk density of a compost mixture. It is available at http://www.canr.msu.edu/dept/ans/community/people/rozeboom_dale.html or Swine Nutrition & Production Management, 2209I Anthony, Department of Animal Science, Michigan State University, East Lansing, MI 48824-1225.

Michigan law requires that active animal tissue composting must maintain a C:N minimum of 15:1 and moisture content in the range of 40 to 60%. Each batch of animal tissue compost feedstocks must attain at least one reading of a temperature greater than 130 degrees Fahrenheit in three different cycles of active composting.

Carbon-to-nitrogen ratio. The C:N ratio results from the mix of the carbonaceous bulking agent(s) and the more nitrogenous animal tissue. At the start of composting, the C:N ratio must be estimated with a plan made so that materials are added to a batch so that the C:N ratio range listed above is achieved. The composting process is forgiving and will occur under a range of C:N ratios. However, with outside of the suggested range, problems may occur. If there is too little carbon (low C:N), the high nitrogen supply is converted to ammonia and is emitted from the pile, resulting in odors. If there is too much carbon (high C:N), the low nitrogen supply can limit microbial activity resulting in slow tissue decomposition. Low temperature readings would result in both cases. As a rule-of-thumb, a desirable C:N ratio is achieved by keeping animal tissue density (lbs./ft^3) between 7.5 and 15.

Moisture content. Water is essential for the life and reproduction of microorganisms. It provides an aqueous environment in which both microbes and nutrients move. Water is also necessary for the chemical reactions of life. At the start of composting, the moisture content must be approximated using the moisture content of your animal tissue and bulking so that the range listed above is achieved. Active composting will fail to occur if the materials are too wet or too dry. Moisture needs to be assessed during the process. If becoming too wet, materials will form a ball or drip when squeezed by hand. Aeration must be used to restart active composting. During the composting process

water will be lost through evaporation. Evaporation is a mechanism for cooling the compost feedstocks, however it also dries the materials. If becoming too dry, water should be added.

Oxygen concentration. Both anaerobic and aerobic activity occurs before the mixing or aeration of animal tissue compost feedstocks, as micro zones of airlessness exist inside the carcass or within the layers of tissue by-products. Here, anaerobic microorganisms work to decompose the tissues, releasing nutrients, fluids and gases which disperse into the surrounding bulking agent. This interface, where tissues, products of anaerobic decomposition, and bulking agents meet, is a critical aerobic micro zone. In properly managed composting, the proportion of activity should be increasingly aerobic. Aeration by turning or moving or mixing the compost batch infuses air into the materials and provides a desired oxygen concentration of 5 to 20%. Measurement or monitoring of oxygen concentration is not required.

Bulking agent particle size or porosity is important in maintaining aerobic conditions within the pile. If too fine, then oxygen will be lacking, activity limited, and odors produced. Fine particles however, are absorbent and help capture fluids released from tissues during composting. If too coarse, then there is to little interface between tissues and the carbon source, limiting microbial metabolism. Excessive coarseness also provides too much air which cools the material. A non-uniform, particle size range of 0.1 to 2 inches is recommended providing porosity, optimal surface area, and absorption. Examples of bulking agents which may be used alone or in a mixture are listed in the TERMINOLOGY section of this document. Density or bulk density is a measure of weight per volume (e.g. lbs./yd^3) and should be in the range of 800 to 1200. In this range, the amounts of air and moisture in the composting materials are suitable for microbial livelihood.

pH. Active composting will not occur outside a pH range of 5.5 to 9.0. Acidity slows composting and a basic pH (> 8.5) promotes the conversion of nitrogenous compounds to ammonia. In most cases the pH does not need to be adjusted because of the natural buffering capacity of the composting pile. It does not need to be monitored. Do not use acidic feed stocks (<5.0) or basic feed stocks such as dairy bedding with a high proportion of lime.

Temperatures. The rise in temperature (degrees Fahrenheit), range of 100 to 150 is an indicator or outcome of composting activity and microbial respiration. Within this range, temperatures enhance microbial reproduction, with greater temperatures being lethal for composting organisms. Temperatures within each batch must reach 130 degrees Fahrenheit at least once before aeration, even in winter provided that bulking agents and animal tissues are not frozen when the batch is initiated. Otherwise, low temperatures can be caused by lack of moisture or oxygen, too much moisture, inappropriate C:N ration, or too few nutrients remaining as in the curing phase. Temperatures greater than 150 degrees are not desirable. When zones of high temperature are immediately adjacent to very dry bulking material, combustion is possible. Maintaining proper moisture content throughout the material prevents fires. The porosity of the bulking agent also promotes aeration and removes heat.

Active composting will continue in cold weather, but addition of frozen tissue should be avoided. Frozen animal tissue if placed in fresh bulking agent will not begin active composting in cold weather, but will do so as ambient temperatures increase in spring. Animal tissue placed in warm amendment during cold weather will decompose without delay.

MANAGING THE COMPOSTING PROCESS EFFECTIVELY

For all animal tissue composting systems Michigan law requires that:

- Composting methods shall accommodate only normal daily natural mortality under common ownership, and be designed with capacity for active composting and curing if it is done. Any increase in mortality, due to any cause known or unknown, shall be reported to the MDA Director immediately. No tissue resulting from such an increase in mortality shall be composted without permission from the Director. More than one species may be composted in the same batch.
- Dead animals must be added to a compost batch within 24 hours of death.
- The temperature 1 foot within the compost batch must be monitored and recorded once weekly, except twice per week for a rotating drum, continuous flow, in-vessel system.

  - Comment: The temperature should reach a minimum of 130 degrees Fahrenheit. During active composting the temperature of compost feedstocks may remain in a range of 100 to 150 degrees Fahrenheit for several weeks, until decreasing. When compost temperatures have been from ambient to 100 degrees Fahrenheit for one to two weeks, it should be aerated.
- Each batch of composting animal tissue must undergo a minimum of three heat cycles (active composting) before final utilization as finished compost.
- Flies, rodents, and vermin are controlled so as not to be a health hazard to human or other animals.
  - Comment: Scavenging vermin may be controlled with use of a perimeter fence (chain-link or equally-restrictive) with gate or gates, around the compost site. A fleece blanket (synthetic fabric which sheds precipitation but allows normal composting respiration) to cover composting materials may also be used. A biofilter cap will help minimize the attraction of intruders. In addition, minimal fly, rodent, pest, vermin, and other scavenger activity will be achieved when compost feedstocks are correctly mixed and aerated. Control measures must not disrupt the composting process.
- Finished compost has no visible pieces of soft tissue and that the bones remaining at the time of final utilization shall be fully decomposed, or easily crumbled during the mechanical spreading process, or gathered and placed in a new batch of compost feedstocks for further decomposition.
  - Comment: Additional biosecurity precautions should be taken and may include: cleaning and drying of transportation vehicles or not using the same loader to mix compost materials and feed livestock without doing so.
- A composting system must be designed with a batching schedule. The owner or operator of the composting system shall keep records for 5 years containing all of the following information:
  - The start date of each compost batch.
  - The quantity of dead animals' or afterbirth added each time an addition is made and the dates the tissue is added to new compost batches.
    - Comment: Animal tissue additions to a new pile should be concluded in two months or less to facilitate proper management of the compost batches.
  - The internal temperature of each actively composting batch measured weekly, except twice per week for a rotating drum, continuous flow, in-vessel system. The internal temperature of curing material measured once each week.
  - The date compost material is aerated if done with loader or turning equipment.
  - The final disposition of finished compost, including the method, location, date, and volume for the batch.

The goal in determining the capacity of the composting process is to have enough space and time for the normal flow of tissues in and achieving the desired quality of finished compost out. Michigan State University research has confirmed that an animal tissue density of 10 lbs./ft^3 or less provides an acceptable nutrient mix for composting. The space or size of the compost system will depend on the amount of animal tissue accumulated on a daily basis. For animal production operations size and maturity of carcasses and the mortality rates for specific production phases are considered. For an animal process operation, animal tissue by-products accumulation may be best estimated from the business records of recent years. The size of the compost system will also depend on the time a compost batch is planned to occupy the designed space. That time is minimized when management practices maximize composting activity over time. The conditions described above are important, but composting time may also be influenced by the carcass temperature at time of introduction into compost batch, the temperature of bulking agent at time of starting a batch, and any increase in the amount of animal tissue surface area exposed (e.g. cutting of carcass flanks, abdomen, muscles; carcass disassembly into smaller parts; grinding). Curing increases space required by about 2 to 3-fold depending again on the extent of previous composting activity and the management of the curing batch. Curing of animal tissue compost, in part or whole, is not required by Michigan law. Size of the compost bins, pad, and windrows will also depend on the size of equipment. Bin width should be at least 1 foot wider than the loader bucket used to move the compost feedstocks.

Static passively aerated batches (bins, windrows, open piles) are not generally designed or operated to maximize composting activity and minimize composting time. The time limits in the literature for the duration of the active composting process vary considerably. In some publications, authors devise equations for predicting bin, pile or windrow size, all static batches, but make educated assumptions about time to decompose and a coefficient is placed in that equation based on the subjectivity of the author or authors. Often, time to compost is included in a number describing pounds of tissue per cubic foot of space.

The number of months of well-managed active composting in static batches for the decomposition of all soft tissues is shown in Table 4 below for carcasses of various sizes. These times are used in the *Spartan Compost Sizer* **(**Department of Animal Science, Michigan State University,, http://www.canr.msu.edu/dept/ans/community/people/rozeboom_dale.html**)**. Mature swine hides will take longer than mature bovine or horse.

Table 4. Months of active composting suggested for the decomposition of soft animal tissues.

Carcass size, pounds	Suggested number of months for well-managed active composting in static batches for the decomposition of all soft tissues
1 to 25	2
25 to 125	3
125 to 250	4
250 to 500	5
500 to 1000	6
1000 or more	8

Actively or forced aerated batches (bins, piles, windrows or contained vessels) require up to 50% less time. It has been reported that composting hog farm mortality using the traditional static batch splayed carcass bin system was a 180-day process, but with the grinding of carcasses and the use of a rotating drum system composting time was reduced to 120 days or less (as low as 75 days).

Compost from a finished or curing batch may be used as bulking agent in a 1 to 1 mix with fresh bulking agent material to begin a new, active compost pile or batch.

Water may be added to compost feedstocks in a manner that raises moisture content of the pile to a level of 40 to 60%, but the addition of water should not create or cause runoff or leachate that leaves the composting site. Precipitation may serve as added water. Batches that get too wet from precipitation should be aerated (preferably turning, moving or mixing) immediately so that active composting resumes.

Bins, piles and windrows.
For bin, pile and windrow animal tissue composting systems Michigan law requires that:

- Initially, the compost pile should be constructed with a base of dry absorbent bulking agent that is at least 1 foot deep before any dead animal is added for composting. A base depth of 2 feet is recommended for large dead animals.
- Animal tissue should not be placed in the pile closer than 6” away from any wall or pile edge.
- Animal tissue should always be covered by a minimum of 6” bulking agent and never be exposed.

Furthermore, a person should manage the composting process in piles (bins, open-static and windrows) in compliance with all of the following provisions:

- Dead animals and bulking agent may be added in layers. It may not be possible to layer large whole carcasses, but they may be laid immediately adjacent to one another. Do not layer large (greater than 500 pounds) carcasses.
- Wetting the animal carcass before covering accelerates the composting process.
- If manure or spoiled feed is used as a bulking agent, add thin layer around animal tissue.
- The final layer on a static pile which will remain undisturbed for longer than one week, serves as a biofilter cap, and should be at least 3 inches of one of the fresh bulking agents listed above, with a high C:N.
- The total depth of the pile should not be more than 6 feet.
- Actively composting materials in static piles must be actively (mechanically turned, mixed, moved) aerated a minimum of two times and undergo a minimum of three heat cycles before final utilization as finished compost.
- Make sure all animal tissue is covered with biofilter cap after aeration.
- Aeration enhances the curing process, but a minimum frequency of aeration events during curing is not required.

Forced-air bins, piles and windrows.

- Procedures required by Michigan law in forming a compost batch using forced-air bins, piles and windrows are similar to those listed above for passively aerated systems.
- The base layer of the batch should be porous, like wood chips or straw.
- Monitor moisture as blower's dry compost feedstocks quickly.
  - Moisture content, range of 40 to 60 % may be monitored using microwave procedure:
    1. Measure 100 to 200 grams of material onto a clean paper plate with a known weight.
    2. Place the plate and material in a microwave oven. Do not spill.
    3. Heat on high for three minutes.
    4. Remove the plate and material and let it cool in the dedicator for two to three minutes.
    5. Weigh the plate and material and record the weight in the notebook.
    6. Place both back into the microwave, heat on high for two more minutes, cool, weigh, and record the weight in the notebook.
    7. Place the sample back into the microwave, heat on high for one more minute, cool, weigh, and record the weight in the notebook.
    8. Repeat step 7 until the weight stays the same for three consecutive weighing cycles.
    9. The initial weight of the material minus the final weight equals the total moisture in the original sample.
    10. Divide the dry weight by the wet weight equals the percentage of dry matter in the material. Subtracting this value from 100 will give the percentage of water in the compost material.
- Add moisture slowly to avoid leaching.
- Aeration may also dissipate heat and cool compost materials. Operate blowers on scheduled intervals.
- Must clean forced-air system periodically.

In-vessel or contained systems.

A variety of containers may be used, with passive, forced, or active aeration. Three heat cycles are required by Michigan law, but all three may not be experienced while material is inside the container. The in-vessel system must be designed to retain animal tissue accumulations for a planned duration. If operated as batches, animal tissue not added daily, must be stored according to Michigan law until composted.

Static container

Batches may be started using layers of bulking agent and animal tissue if left passive in the container for a short-term (3 to 10 days) or if a floor or wall forced air system is used.

- Mix according to desired C:N and moisture contents.
- Placing a base layer of bulking agent in container.
- Container can be filled gradually over short period (e.g. one week)
- Layer animal tissue and bulking agent
- In forced aerated systems, bulking agent and animal tissue should be well-mixed during loading.
- Some static in-vessel systems require emptying and reloading during active composting to enhance activity.

Rotating drum

- In rotating systems, rotation may follow a static period or may be continuous. Mix according to desired C:N and moisture contents. Water additions must be made slowly (e.g. less than 2 gal/minute) to prevent leakage from container.

  For batch composting
  - Bulking agent and animal tissue may be placed in layers and let sit static for the first 1 to 2 days.
  - After the start of constant rotation, compost materials will dry quickly with a heat cycle being about one week. If dry, bones tend to polish rather than decompose.
  - Three heat cycles may be experienced over the course of several weeks, while in the container if the composting system is designed to keep feedstocks within the container for that duration. At least three containers would be needed if new tissue was accumulated and a new batch began each week.
  - Alternatively, composting may be in-vessel for a shorter period, after which the material is allowed to continue the composting process over several months elsewhere on-site, going through two additional required heat cycles.

  For continuous flow composting
  - Bulking agent and animal tissue added according to recipe.
  - Order of bulking agent and animal tissue additions is not critical.

- Rotation is stopped momentarily for additions.
- Removal occurs through openings as the drum rotates.
- The process may include the addition of animal tissue and bulking agent daily, and the removal of unfinished compost daily.
- Retention time must be three days or more.
- The temperatures in the rotating drum system operated on a continuous flow basis, will be consistently 130°F provided moisture and air are present at optimal amounts. Temperature of rotating drum systems must be recorded twice weekly to assure that all animal tissue has been exposed to one heat cycle prior to removal from the container.
- After the first heat cycle inside the drum, material must be allowed to continue the active composting process elsewhere on-site, going through two additional required heat cycles.
- After the start of constant rotation, compost materials will dry quickly with a heat cycle being about one week. If dry, bones tend to polish rather than decompose.

PROBLEMS

On-farm mortality and tissue by-products are a part of producing food for humans. Properly managed composting recycles the nutrients in animal tissues with control of odors, insects, vermin and disease. Management can correct problems.

- Soft tissue remaining typically indicates lack of activity. This may be a result of too low or high of C:N, too dry or too wet, and failure to complete three heat cycles of temperatures higher than 130°F. In passive piles or windrows, lack of oxygen may also contribute to lack of activity and aerating more frequently (suggest once per month or twice per month) will increase activity. Aerate based on temperature.
- Odor is an indicator of an inappropriate recipe and inadequate activity. Materials may be too wet, to nitrogenous, or not aerated sufficiently. Odor also results from animal tissue being inadequately covered.
- Low temperature is an indicator of inadequate activity and may be caused by materials being too wet or too dry, or inappropriate C:N ratio, or too much aeration (cooling the feedstocks).
- Dry pieces of hide remaining are due to lack of moisture. Drying preserves tissues.
- Leachate is a result of excessive moistures.
- Flies and animals result from inadequate cover and lack of heat.

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